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THE ANTICIPATORY EFFECT, A STUDY OF THE BURNING MECHANISM OF DELAY-RELAY COLUMNS

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OBJECT

To investigate the burning characteristics of delay columns pressed above terminal charges of thermally sensitive relay material.

ABSTRACT

A newly recognized phenomenon termed the anticipatory effect is reported and its probable mechanism discussed. This effect occurs upon the burning of delay columns pressed above typical relay and flash charges and is reflected, in some systems, by more than a 40% diminution of burning time when no thermally sensitive terminal charge is present.

An important mechanism operative in propagative columnar burning of pressed delay composition is the passage of hot gases through pores of the column. These gases, reaction products of the burning delay composition in the upper portions of the column, evidently precede the flame front of the column and have been shown to ignite a terminally loaded relay charge at times shorter than would have been expected were the flame front alone the initiating source for the terminal charge. This effect has practical significance as it relates to end item performance. In this investigation the anticipatory effect was characterized for columns in which various delay and terminal charge compositions were used.

CONCLUSIONS AND RECOMMENDATIONS

1. Burning characteristics of representative pressed delay compositions undergo considerable change when loaded above a thermally sensitive terminal charge. Reduced burning time and decreased burning time reproducibility have been found under these conditions.

2. This phenomenon, the so-called anticipatory effect, occurs for the non-gaseous and gaseous delay compositions pressed over a variety of thermally sensitive materials as terminal increments. In addition, the effect was found for a typical end item delay element having a lead styphnate-lead azide relay.

3. The extent of burning time diminution that occurs with delay columns having thermally sensitive terminal charges (compared to similarly pressed columns with no terminal charge) appears to approach a constant value as column length above the terminal charge increases.

4. The extent of burning time diminution occurring with several $BaCrO_4/B$ compositions is a function of the burning rate of these compositions. The more rapid burning compositions show less burning time reduction.

5. The degree of anticipatory effect is substantially increased upon obturation of the delay columns.

6. The importance of gas permeation as a mechanism for heat transfer in the burning of pressed delay composition has been indicated, suggesting that future studies be conducted to determine the effects of column porosity on delay column burning characteristics. In addition, the extent to which gas passes through the delay column during the time of burning will be an important consideration.

7. Effects of temperature, pressure, and particle size on the anticipatory effect should be studied.

INTRODUCTION

The importance of thermally sensitive materials as igniters of delay columns has long been recognized. Studies in the Pyrotechnics Laboratory at Picatinny Arsenal have given some indication of the role of the igniter in the burning of pressed delay columns. Elsewhere, Marcus (Ref 1) has conducted a rather detailed investigation concerning the effect of igniters on the burning characteristics of tungsten/barium chromate/potassium perchlorate/superfloss delay powders having burning rates in the range of 30 seconds per inch. Mention was made of the placement of igniter material as a terminal charge in delay columns and its apparent lack of effect on burning times.

The studies discussed in this report, however, specifically relate to the pronounced effect that such terminal charges have on burning characteristics of representative delay compositions. These investigations demonstrate the consistent sizable decrease in burning time and its reproducibility that occurs when a delay composition is pressed above a terminal charge of thermally sensitive material. The results are significant as they apply to the performance of delay-relay units where specific burning times at high levels of reproducibility are desired.

The present work has been directed toward determining the extent of this decrease in burning time and toward establishing the mechanisms operative in this effect. Work planned for the future will concern the minimization of this anticipatory effect by physical and chemical means.

RESULTS AND DISCUSSION

In an investigation of the functioning characteristics of igniter materials used as first-fire increments for delay columns, an effect was observed which is important in its connection with the performance of delay-relay units. Studies were conducted to determine whether, in essence, the output from a first-fire increment by-passes a portion of the delay column and results in a diminution of the burning time. It was suspected that this might be so, for during work in which burning times for delay columns were obtained with and without first-fire increments reductions in burning times were often obtained when igniter material was used.

Such a decrease could be attributable to either more rapid ignition of the column (from squib) through ease of ignition of the first-fire or as a

by-pass of a portion of the delay column proper through first-fire output. Experimental work involved the pressing of a 100 mg increment of SI-98[1] igniter composition as an internal charge between upper and lower 250 mg charges of 95/5 $BaCrO_4$/B delay composition. Decreased burning times, under these conditions, would have been considered to indicate that output from the igniter was affecting the uniformity of the columnar burning and that a small portion of the delay composition immediately under the igniter increment was not contributing to the burning time of the column.

Data obtained from this experiment did indeed demonstrate a reduction in burning time but to such a degree that igniter output could not alone have been the cause. In Table 1 (p 12), data is shown indicating a 45% (183 msec) reduction in burning time. Positioning of igniter material as a first-fire increment never produced more than a 20 msec reduction in burning time, indicating that the observed effect was attributable to a response to some mode of heat transfer by the igniter that did not occur when the delay composition alone comprised the column. To ensure that igniter output would not contribute to a reduction of burning time, 100 mg increments were pressed as a terminal charge below 500 mg increments of the delay composition.

A comparison of the burning times so obtained with those of columns containing the delay composition alone is shown in Table 2 (p 13). Here again a very pronounced reduction in burning time occurs, amounting to 41% of the burning time with the 95/5 $BaCrO_4$/B columns alone. Repetition of this experiment substantiated these results. The reduction in burning time was even more evident, dropping from an average value of 464 msec with the delay column alone to a corresponding value of 158 msec, a 66% reduction. This data is shown in Table 3 (p 14).

It is important to note that not only does a decrease in burning time attend the positioning of a terminal charge of thermally sensitive material but, significantly, there is also a considerable reduction in burning time reproducibility. Tables 1, 2, and 3 show percent range values for the three sets of data referred to above. The decrease in reproducibility level (increased percent range) could indicate a lack of uniformity in the mode of heat transfer to the terminal charge.

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[1]SI-98 composition, 26/21/53 $MoO_3/KClO_4/Zr$.

Studies were next conducted in which the extent of the burning time reduction (or anticipatory effect) was found for two other more rapidly burning $BaCrO_4/B$ compositions, the 90/10 and 86/14, in addition to the 95/5 composition investigated previously. Here again 100 mg increments of SI-98 were used as the terminal charge, being pressed as the lowermost increment. Controls were prepared concurrently, with all loading being done at 36,000 psi. Shown in Table 4 (p 15) are the average burning times obtained for these systems.

It would appear that the extent of burning time reduction obtained for columns having SI-98 as a terminal charge is related to the burning rate of the delay composition pressed above it. The slower the burning rate of the delay composition the more pronounced is the decrease in burning time relative to similarly pressed columns in which no terminal charge was used. These results apply to the $BaCrO_4/B$ system.

Significant results have been obtained in the study of the anticipatory effect in end item hardware. Recoilless Daisy delay housings were loaded with two 400 mg increments of 86/14 $BaCrO_4/B$. A number of items were prepared with lead styphnate-lead azide relay cups in place while the balance were loaded with delay composition alone. For elements loaded with no relay an average burning time of 156 msec was obtained with a percent range of 9.6. For columns prepared with relays an average burning time of 136 msec was obtained with a percent range of 13.0. It is seen that a decrease in reproducibility again attends the burning of items in which a thermally sensitive terminal charge is present.

Following this study, the responses of five different compositions were investigated to determine the extent of the burning time reduction when they are loaded as terminal charges below 500 mg increments of 95/5 $BaCrO_4/B$. In Table 5 (p 16) values for burning times so obtained are compared to corresponding values for burning times of columns prepared with 95/5 $BaCrO_4/B$. These results may be considered, in general, to reflect the relative ease of ignition for these five compositions and their response to heat transfer through whatever mechanism occurs.

A characteristic of the anticipatory effect is the leveling off of the extent of burning time reduction as the column length above the terminal charge is increased. This effect was demonstrated in three individual experiments in which the extent of the anticipatory effect was determined as a function of column length. The value ΔBT appearing in Tables 6, 7,

and 8 (pp 17, 18, and 19) denotes the extent of burning time reduction resulting from positioning of the terminal charge below the delay column. It is the difference in the average burning times for similar columns loaded with and without the terminal charge. The leveling off of this ΔBT value is shown for two separate batches of 95/5 $BaCrO_4/B$ composition and for the 55/35/10 $W/BaCrO_4/KClO_4$ composition.

In the latter experiment, the initial column height provided by 1000 mg of the delay composition was evidently such that the extent of burning time reduction no longer changes significantly when the length of the column is increased. The decrease in burning time reproducibility upon positioning of the terminal charge should be noted. The data is shown in Table 8.

The mechanism by which the anticipatory effect occurs has been investigated through several experiments in which barriers of inert material were placed between the delay column and the thermally sensitive terminal charge. The purpose of this work was to determine the depth of various buffer materials through which sufficient heat transfer could occur to allow for ignition of the terminal charge. The extent of burning time reduction with 95/5 $BaCrO_4/B$ compositions pressed over a terminal charge of SI-98 would indicate that a very considerable portion of the column is being by-passed, presumably by hot gases that are produced by burning of composition at the upper end of the column. This was recognized in an investigation by Scott (Ref 2). This burning time reduction is illustrated by the data in Table 1 which shows that an average burning time of 403 msec was obtained for a column of 500 mg of 95/5 $BaCrO_4/B$. A corresponding value of 220 msec was obtained for a similar column in which 100 mg of SI-98 was pressed as a terminal charge. This represents a reduction of 45% in the burning time of the delay column alone and indicates that nearly one-half of that column does not contribute to the effective burning time of the column.

It is of interest to note that when individual values in these groups of data are considered, the effect can be even more extreme. As an example, in Table 3 (p 14) the low value for the delay column of 95/5 $BaCrO_4/B$ alone is seen to be 444 msec. The low value for a similar column pressed over a 100 mg terminal charge of SI-98 is 61 msec, an 85% reduction in burning time. That only 15% of the column length effectively contributes to the burning time of this delay-relay element is quite surprising. The mechanism of hot gas permeation has been suggested for this anticipatory

effect and experimental evidence cited below would appear to substantiate this.

Before experimental results with barrier materials are discussed an alternate mechanism, may, however, be considered as being a possible cause for the reduced burning times observed. Such an effect may arise from the conduction of heat through the walls of the housing. The rate of heat transfer by this means must, of course, exceed the rate of propagation for the burning front. If either or both mechanisms are operative, it can be assumed that, with the faster burning compositions, such as 90/10 and 86/14 $BaCrO_4$/B, the burning front does not lag behind the other paths for heat transfer to as great a degree as in the case of the slower burning 95/5 composition.

It would seem doubtful that heat transfer to the terminal charge occurs by way of conduction through walls of the delay housing. This was demonstrated in studies by Nakahara and Hikita (Ref 3) who found that the temperature rise begins much sooner at the center of a burning delay column than in the peripheral areas 1 mm from the wall of the housing. This would clearly indicate that heat transfer to the lower portions of the column would occur by way of its central portion.

Barium chromate was used in the first studies in which inert barrier material was placed between the delay column and the thermally sensitive terminal charge. The $BaCrO_4$ in this study was identical with that used for the delay composition, thereby providing a buffer having a density and porosity very similar to those of the delay column itself. Various amounts of $BaCrO_4$, ranging from 85 mg to 285 mg, were used. The amounts of 95/5 $BaCrO_4$/B composition pressed above the barrier in these columns ranged from 415 to 215 mg, the total weight of barrier and delay composition being 500 mg for all loadings. Burning time data for this study is shown in Table 9 (p 20). The number of items functioning in each group is also shown. Control trials were conducted in which burning times were obtained for the delay composition alone and for the delay composition pressed above the SI-98 terminal charge.

The pressing of 125 mg of $BaCrO_4$ between the delay column and the terminal charge appears to result in marginal propagation through the column. That greater depths (weights) of this buffer result in almost complete inhibition of propagation complicates the consideration that the anticipatory effect arises through passage of hot gases ahead of the burning

front. It would be expected that a 230 mg depth of $BaCrO_4$, equal to the amount of 95/5 $BaCrO_4$/B that would provide a 240 msec burning time, should allow for propagation throughout the column. The 240 msec time interval represents the average burning time reduction observed with a 500 mg column of 95/5 $BaCrO_4$/B pressed over 100 mg of SI-98 and represents the bypassing of 230 mg of composition. Thus, a 230 mg buffer of $BaCrO_4$ should allow burning to precede down the entire column.

In another study involving the use of barriers, separate experiments were conducted in which an aluminum relay cup with 0.01-inch-thick walls and a 0.021-inch-deep bed of 9-micron copper powder were loaded above a 100 mg SI-98 terminal charge and below the 95/5 $BaCrO_4$/B delay column. The cup bottom[1] was placed above the terminal charge and increments of delay composition were loaded in the usual manner. The copper powder was loaded as an additional increment between the terminal charge and the delay column. A loading pressure of 36,000 psi was used in all cases, controls being prepared with similar amounts of delay composition pressed alone and over a terminal charge of SI-98. Data for this study is shown in Table 10 (p 21). For the delay composition alone, an average burning time of 638 msec was obtained.

For similar columns pressed over the sensitive terminal charge, the average burning time decreased to 532 msec. An average value of 595 msec was obtained for trials in which the copper powder barrier was placed between the delay column and the terminal charge. In the case of elements prepared with aluminum cups, the terminal charge was not ignited, insufficient heat evidently being passed to the lowermost increment. These results are important in demonstrating the mechanism responsible for the anticipatory effect and are substantiated by additional studies in which charges of aluminum powder of different sizes and shapes were placed between a 1000 mg column of 95/5 $BaCrO_4$/B and a terminal charge of SI-98. The weight of aluminum used was 45 mg. Burning times were obtained for three groups having spherical particles 6, 30, and 160 microns in diameter. In all cases the terminal charge underwent ignition. However, when an equal weight of flake aluminum (nominally 1 micron average particle diameter) was used as the barrier, ignition of the terminal charge did not occur. Apparently, the laminar disposition of flake aluminum does not allow any

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[1]Relay cup for M112 photoflash cartridge fuze housing.

passage of hot gases to occur and ignition of the terminal charge could not be effected. Data for this experiment is shown in Table 11 (p 22).

In further experimental studies, it was shown that the extent of the anticipatory effect is more pronounced when burning of columns occurs under obturated rather than vented conditions. Summarized in Table 12 (p 23) is data for trials in which one 500 mg increment was loaded alone and also above 100 mg of SI-98 composition. Columns thus prepared were burned under vented and obturated conditions. SI-98 squibs were used in this study and were pressed directly against the upper face of the delay column and sealed over with epoxy resin[1]. The rate of gas passage through pores of the delay column would be expected to be greater under obturated conditions where gaseous pressure cannot be relieved through the upper end of the column. Burning time is reduced 54% under obturated conditions compared to 20% under vented conditions.

Another experiment was conducted in which two 500 mg increments of 95/5 $BaCrO_4/B$ were pressed over 100 mg of SI-98. A thin transparent film of epoxy resin[1] was applied to the terminal end of the housing. Similar columns were prepared without the epoxy seal and also without seal and terminal charge. For the group with no terminal charge, an average burning time was reduced to 510 msec, but for the group in which the terminal seal was used the average burning time was 635 msec. In this experiment, the terminal seal presumably resisted gas flow through the column, and heat transfer to the terminal charge occurred less rapidly than in the absence of this seal. Data from this experiment is shown in Table 13 (p 24).

The experimental results discussed point to gas permeation as the mechanism by which the anticipatory effect occurs. This effect, as has been shown, is quite pronounced and could be responsible for considerable reduction in burning time and burning time reproducibility in end items having relay units positioned at the terminal end of a delay column. The practical considerations arising from this work are quite significant because they relate to the design and performance of delay-relay units. Items currently in use may not be functioning at reproducibility levels as high as would be obtained in the absence of the anticipatory effect.

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[1]Epon 828 resin, C14B catalyst 10 parts to 1 part.

Improvement in the performance of delay-relay units may require a dual approach. Not only would the chemical and physical characteristics of the column be considered but also the positioning and geometry of the relay unit.

EXPERIMENTAL PROCEDURE

Materials

Boron, American Potash Co., Lot 384h, 1 micron

Barium chromate, J. T. Baker Co., Lot 4608, 1 micron

Molybdenum (VI) oxide. J. T. Baker Co., Lot 792635, 5.6 micron

Potassium perchlorate, Oldbury Electrochemical Co., Lot 3347, 31 micron

Zirconium, Foote Mineral Co., Lot 691467, 2.7 micron

Copper, Fisher Scientific Co., Lot 461802, 9 micron

Aluminum, Valley Metallurgical Processing Corp., spherical particles, 6, 30, and 160 micron

Aluminum, Allied Chemical Co., Lot 1-62, Type A, Class A, Flake, 0.9 micron

Chromic oxide, Fisher Scientific Co., Lot 763758, 0.5 micron.

Burning Time Determinations

M1A1 electrical squib housings containing SI-98 composition[1] were used to ignite all delay columns. A 24-volt dc wet cell source was used for squib initiation.

The timing circuit provided for simultaneous actuation of squib and counter at initiation of columns and photocell response to stop counter

[1]SI-98 composition, 26/21/53 $MoO_3/KClO_4/Zr$.

upon light flash from terminal end of the column at completion of burning. The counter employed was the Potter Company Model 456, 1.6 megacycle chronograph. All values for burning time shown above include a combined squib burning time and instrument response time amounting to approximately 11 msec.

Test Conditions

All work was conducted under ambient pressure and temperature.

Loading

Compositions were pressed in 1-sec fuze housings for the M112 photoflash cartridge. A drawing of this item appears as Figure 1 (p 25). All pressing was done at a one-ton dead load, providing a loading pressure of 36,000 psi.

REFERENCES

1. Marcus, I. R., *Development of a Split Igniter for Initiating Gasless Delays,*" Diamond Ordnance Fuze Laboratories Report TR 875, 14 November 1960

2. Scott, A., *Pyrotechnic Delay Studies in the United Kingdom,* Armament Research and Development Establishment, Langhurst, Hersham, Sussex, October 1961 (Confidential)

3. Nakahara, S. and Hikita, T., "Measurement of Temperature of Combustion of Delay Powders," *Journal of the Industrial Explosives Society of Japan, 20,* 275-9, 1958

TABLE 1

Burning characteristics of 95/5 $BaCrO_4$/B columns with and without an internally pressed charge of SI-98 igniter composition

Trial	Burning Time, msec: Delay Column Alone	Burning Time, msec: Delay Column with Internally Pressed SI-98
1	414	269
2	455	251
3	475	213
4	416	193
5	433	186
6	432	197
7	367	246
8	409	191
9	409	207
10	375	321
11	370	202
12	393	204
13	440	192
14	381	238
15	337	209
16	414	232
17	406	197
18	334	214
Average	403	220
Percent Range	35	61

For columns of delay composition alone, one 500-mg increment of 95/5 $BaCrO_4$/B was used.

For columns with internally pressed charge, 250-mg increments of 95/5 $BaCrO_4$/B were pressed above and below a 100-mg increment of SI-98 igniter composition. SI-98 squibs were employed for initiation of columns. Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 2

Burning characteristics of 95/5 $BaCrO_4$/B columns with and without a terminally pressed charge of SI-98 igniter composition

Trial	Burning Time, msec Delay Column Alone	Delay Column with Terminally Pressed SI-98
1	474	250
2	468	338
3	476	257
4	490	310
5	493	293
6	492	254
7	497	259
8	431	287
Average	478	281
Percent Range	13.8	31.3

For columns of delay composition alone, one 500-mg increment of 95/5 $BaCrO_4$/B was used. For columns with terminally pressed igniter charge, a 500-mg increment of 95/5 $BaCrO_4$/B was consolidated above a 100-mg increment of SI-98 igniter composition as a single pressing. SI-98 squibs were employed for initiation of columns. Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 3

Burning characteristics of 95/5 $BaCrO_4$/B columns with and without a terminally pressed charge of SI-98 igniter composition

Trial	Burning Time, msec — Delay Column Alone	Burning Time, msec — Delay Column with Terminally Pressed SI-98
1	464	140
2	483	103
3	444	164
4	471	239
5	461	79
6	463	273
7		207
8		61
Average	464	158
Percent Range	8.4	134

For columns of delay composition, one 500-mg increment of 95/5 $BaCrO_4$/B was used. For columns with terminally pressed igniter charge a 500-mg increment of 95/5 $BaCrO_4$/B was consolidated as a separately pressed increment above a 100-mg increment of SI-98. SI-98 squibs were employed for initiation of columns. Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 4

Extent of anticipatory effect as a function of burning rate of various $BaCrO_4$/B compositions

	Average Burning Time, msec		
	95/5	90/10	86/14
Delay composition alone	464	167	132
Delay composition above terminally pressed 100-mg increment of SI-98	158	124	116
Burning time reduction, msec	306	43	16

SI-98 squibs were employed for initiation of columns.

Data for 95/5 results appears in Table 3 where individual values are shown. Data for 90/10 and 86/14 compositions represents average values obtained for sixteen replicate trials in each case. Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 5

Extent of anticipatory effect as a function of terminal charge composition, 500-mg of 95/5 $BaCrO_4$ pressed above 100-mg increments of various terminal charge compositions

			Burning Time, msec			
Trial	Control	DP-875	SI-98	DP-675	DP-1081	SI-129
1	463	391	350	358	281	369
2	435	329	340	358	333	287
3	403	419	302	351	341	289
4	415	416	325	266	280	242
5	533	415	307	368	359	247
6	419	395	302	252	331	354
7	463	407	322	332	295	341
8	489	384	242	305	316	329
9	450	409	349	312	337	230
10	471	420	376	319	288	294
11	444	409	324	310	334	227
12	400		395	340	335	230
13	462		341	332	263	260
14	399		352	325	326	297
15	369		361	348	184	259
Average BT	441	399	332	325	307	284
Δ BT	–	42	109	116	134	157

SI-98 squibs were employed for ignition of columns.

The control group were columns pressed with 500-mg increments of 95/5 $BaCrO_4/B$.

Identification of compositions used as terminal charge:

DP-875	86/14 $BaCrO_4/B$
SI-98	26/21/53 $MoO_3/KClO_4/Zr$
DP-675	51/49 MoO_3/Zr
DP-1081	31.3/20/48.7 $MoO_3/Cr_2O_3/Zr$
SI-129	25.2/16.1/58.7 $MoO_3/Cr_2O_3/Zr$

Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 6

Extent of anticipatory effect as a function of column length
95/5 $BaCrO_4$/B delay composition, Batch 1*

	Average Burning Time, msec	Burning Time Range, msec	Percent Range	Δ Burning Time	% Column By-passed	Length of Column By-passed, in.
One 500-mg increment						
Without terminal charge**	327	63	19			
With terminal charge***	94	183	187	233	71	0.14
Two 500-mg increments						
Without terminal charge	630	77	12			
With terminal charge	321	406	124	309	49	0.20
Three 500-mg increments						
Without terminal charge	925	76	8			
With terminal charge	645	327	50	280	30	0.18
Four 500-mg increments						
Without terminal charge	1207	113	9			
With terminal charge	931	258	28	276	23	0.18
Five 500-mg increments						
Without terminal charge	1501	77	5			
With terminal charge	1144	257	22	357	24	0.24
Six 500-mg increments						
Without terminal charge	1814	110	6			
With terminal charge	1505	243	16	309	17	0.20

*SI-98 squibs were used to initiate the columns.

The composition was loaded in M112 fuze housings at 36,000 psi.

**SI-98 terminal charges were used.

***Average burning time values have been reduced by 6 msec in order to take into account the burning time of the terminal charge itself.

TABLE 7

Extent of anticipatory effect of a function of column length 95/5 $BaCrO_4$/B delay composition, Batch II*

	Average Burning Time, msec	Burning Time Range, msec	Percent Range	Δ Burning Time	% Column By-passed	Length of Column By-passed, in.
One 500-mg increment						
Without terminal charge**	296	54	18.2			
With terminal charge***	221	54	23.8	75	25	0.05
Two 500-mg increments						
Without terminal charge	538	68	12.6			
With terminal charge	418	178	41.9	120	22	0.09
Three 500-mg increments						
Without terminal charge	790	94	11.9			
With terminal charge	659	230	34.6	131	17	0.10
Four 430-mg increments						
Without terminal charge	908	81	8.9			
With terminal charge	788	161	20.3	120	13	0.07

*SI-98 squibs were employed for initiation of columns.

Compositions loaded in M112 fuze housings at 36,000 psi.

**SI-98 terminal charges were used.

***Average burning time values have been reduced by 6 msec in order to take into account the burning time of the terminal charge itself.

TABLE 8

Extent of anticipatory effect as a function of column length
55/35/10 $W/BaCrO_4/KClO_4$*

	Average Burning Time, msec	Burning Time Range, msec	Percent Range	Δ Burning Time	% Column By-passed	Length of Column By-passed, in.
One 1000-mg increment						
Without terminal charge**	2348	411	18			
With terminal charge	1473	462	31	875	37	0.07
Two 1000-mg increments						
Without terminal charge	4291	259	6			
With terminal charge	3404	583	17	887	21	0.09
Three 1000-mg increments						
Without terminal charge	6082	328	5			
With terminal charge	5192	1042	20	890	15	0.09
Four 860-mg increments						
Without terminal charge	6914	337	5			
With terminal charge	6173	990	16	741	11	0.08

*SI-98 squibs were employed for initiation of columns.

The composition was loaded in M112 fuze housings at 36,000 psi.

**SI-98 terminal charges were used.

***Average burning time values have been reduced by 6 msec in order to take into account the burning time of the terminal charge itself.

TABLE 9

Effect of inert buffer on burning characteristics of delay columns with thermally sensitive terminal charge

Weight of 95/5 $BaCrO_4/B$ Column, mg	Weight of $BaCrO_4$ Buffer, mg	Weight of SI-98 Terminal Charge, mg	Average Burning Time, msec	Number of Items Undergoing Complete Propagation
500	None	None	512	10 of 10
500	None	100	272	10 of 10
415	85	100	290	10 of 10
375	125	100	357	5 of 10
350	150	100	432	1 of 10
315	185	100	285	1 of 15
215	285	100	263	1 of 15

SI-98 squibs used for initiation of all columns.

Terminal charge, buffer, and delay composition pressed individually at 36,000 psi.

Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 10

Effect of inert buffer on burning characteristics of delay columns* with thermally sensitive terminal charge

	No Buffer, No Terminal Charge	No Buffer, 100-mg SI-98 Terminal Charge	Relay Cup Buffer, 100-mg SI-98 Terminal Charge	125-mg Cu powders Buffer, 100-mg SI-98 Terminal Charge
Average burning time, msec	638	532	Did not propagate	595
Range	116	104	--	71
Percent range	18.2	19.5	--	11.9
No. trials	15	15	15	15

*Delay column consisted in all cases of two 500-mg increments of 95/5 $BaCrO_4$/B.

Relay cups were those used in fuze of M112 photoflash housing. Wall thickness 0.01 inch.

Cu powder was 9μ average particle diameter. Depth of Cu powder, 0.021 inch.

SI-98 squibs used for initiation of all columns.

Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 11

Effect of aluminum powder buffer on burning characteristics of 95/5 $BaCrO_4$/B delay column with terminal charge of SI-98

Trial	Burning Times, msec, of Two 500 mg 95/5 $BaCrO_4$/B Columns with 100-mg SI-98 Terminal Charge and Aluminum Powder Buffers			
	6-Micron Spherical Al	30-Micron Spherical Al	160-Micron Spherical Al	1-Micron Flake Al
1	614	608	606	
2	639	599	603	
3	530	619	590	Did not propagate past barrier
4	623	617	592	
5	602	610	592	
Average	602	610	597	

SI-98 squibs used for initiation of all columns.

Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 12

Effect of obturation on the anticipatory effect

Burning Time, msec, of One 500-mg Increment 95/5 $BaCrO_4$/B Pressed Over 100-mg SI-98 Terminal Charge

	Without Terminal Charge	With Terminal Charge	% Reduction in Burning Time
Vented	340	260	20
Obturated	37	10	73

SI-98 squibs used for initiation of columns.

In obturated items squibs were pressed directly against the upper face of the delay column.

Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 13

Effect of terminal seal on extent of anticipatory effect

Burning Time, msec, of Two 500-mg Increments 95/5 $BaCrO_4$/B With and Without 100-mg SI-98 Terminal Charge

Trial	Columns with No Terminal Charge and No Seal	Columns with Terminal Charge and No Seal	Columns with Terminal Charge and Seal
1	620	490	634
2	648	545	688
3	634	532	630
4	609	484	596
5	765	475	763
6	688	524	594
7	674	529	639
8	657	532	627
9	696	483	
10	733	502	
Average	663	510	635
Range	156	70	169
% Range	23.6	13.7	26.6

SI-98 squibs used for initiation of columns.

Terminal seal obtained with Epon 828 C14B 10:1.

Composition loaded in M112 fuze housings at 36,000 psi.

TABLE 14

Burning rates and column height–weight correspondence for compositions investigated*

Composition Identification	Formulation		Burning Rate, sec/in.	Column Height, inches per 100-mg Composition
DP-956	95/5	$BaCrO_4/B$	1.58	0.039
DP-933	90/10	$BaCrO_4/B$	0.75	0.040
DP-875	86/14	$BaCrO_4/B$	0.61	0.041
DP-972	55/35/10	$W/BaCrO_4/KClO_4$	7.5	0.021
DP-675	51/49	MoO_3/Zr	0.19	0.028
DP-1081	31.3/20/48.7	$MoO_3/Cr_2O_3/Zr$	0.46	0.029
SI-98	26/21/53	$MoO_3/RClO_4/Zr$	0.16	0.026
SI-129	25.2/16.1/58.7	$MoO_3/Gr_2O_3/Zr$	0.22	0.030

*All compositions loaded in M112 fuze housings at 36,000 psi.

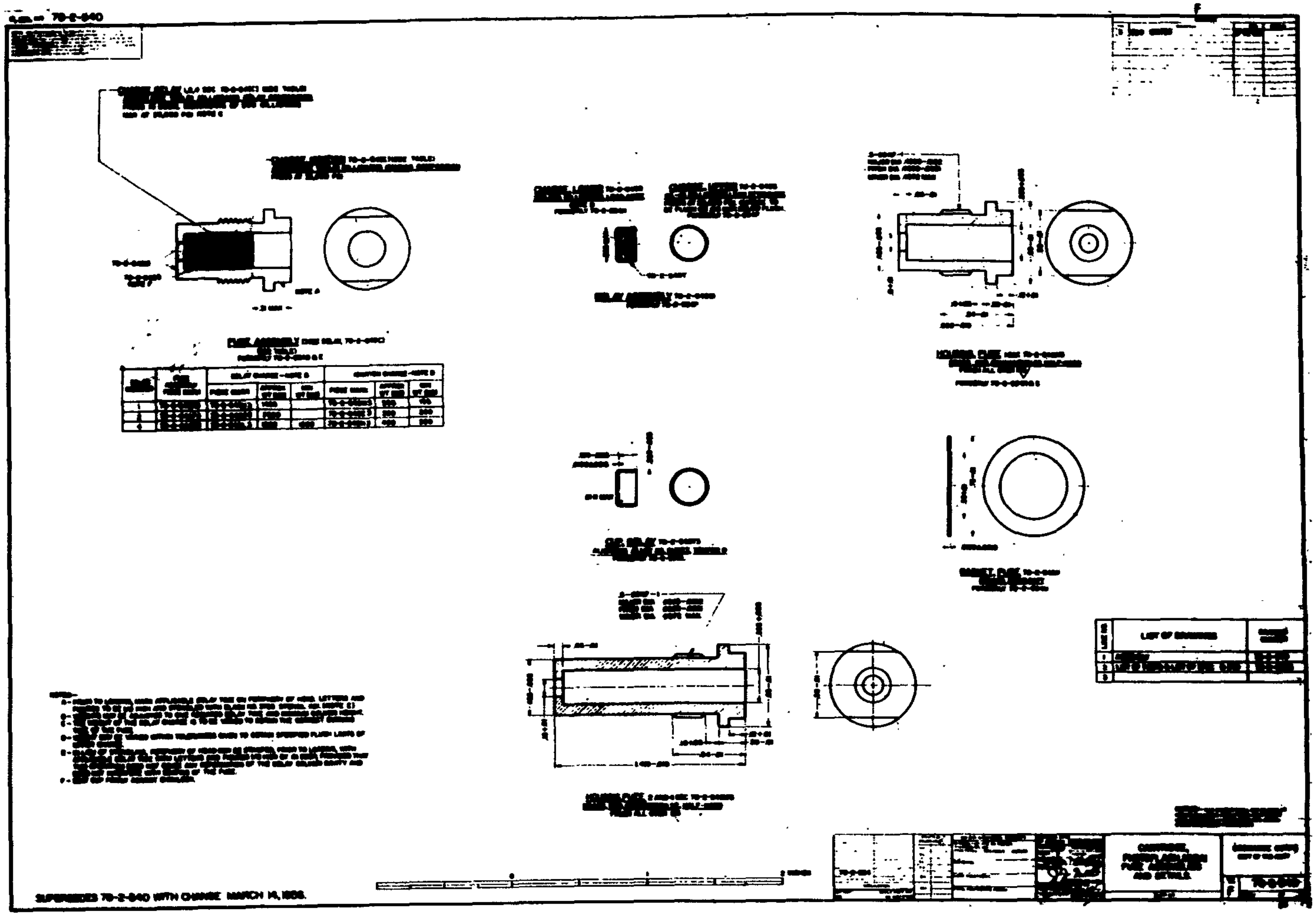

Fig 1 Fuze assemblies and details for M112A1 photoflash cartridge

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Martin Gilford, Burton Werbel, Garry Weingarten, Lindbergh Key

Picatinny Arsenal Technical Report 3047, March 1964, 30 pp, tables, figure. DA Proj 504-01-027, AMCMS 5530. 11.55800. Unclassified Report

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(over)

1. Delay powders — Combustion
2. Delay powders — Porosity

I. Gilford, Martin
II. Title

UNITERMS

Anticipatory effect
Burning time
Delay element
Relay
Igniter composition
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Boron
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